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Phytopathological Classics

NUMBER 3

THE DISCOVERY OF BORDEAUX MIXTURE

Three papers

I. Treatment of Mildew and Rot.
II. Treatment of Mildew with Copper Sulphate and Lime Mixture.
III. Concerning the History of the Treatment of Mildew with Copper Sulphate.

BY

PIERRE MARIE ALEXIS MILLARDET

1885

A Translation by

FELIX JOHN SCHNEIDERHAN

of

Traitement du Mildiou et du Rot. Journ. d'Agr. Pratique, **2**: 513-516. 1885

Traitement du Mildiou par le Mélange de Sulphate de Cuivre et de Chaux. Journ. d'Agr. Pratique, **2**: 707-710. 1885.

Sur l'Histoire du Traitement du Mildiou par le Sulfate de Cuivre. Journ. d'Agr. Pratique, **2**: 801-805. 1885.

With Biographical Sketch and Foreword

by the Translator

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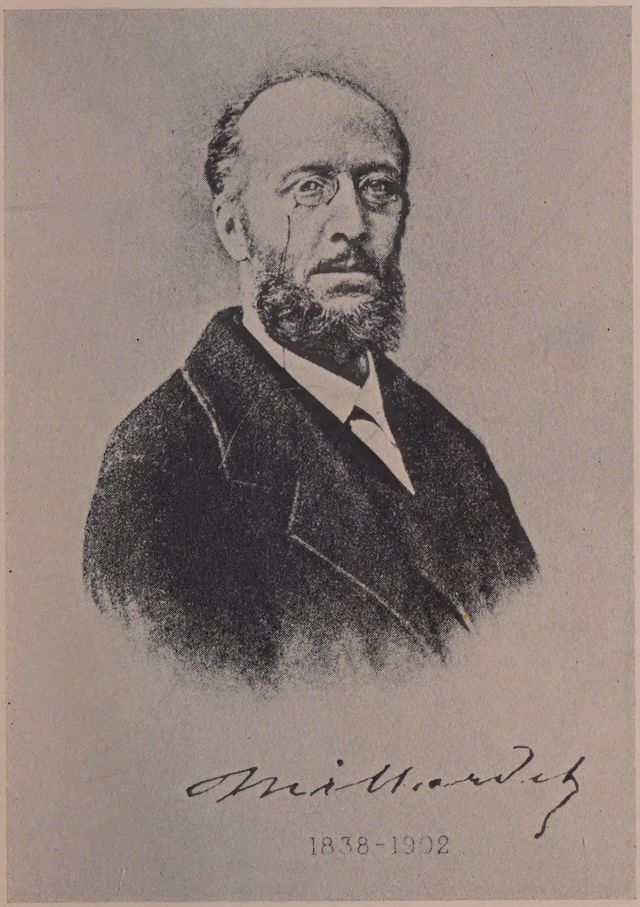
PIERRE MARIE ALEXIS MILLARDET

Pierre Marie Alexis Millardet was born December 13, 1838, at Montmerey-la-ville in the Department of Jura, and died December 15, 1902. He came of intellectual parents and he was thoroughly educated. He first studied medicine but gave up a good practice to study botany, first under Hofmeister at Heidelberg and, later, under de Bary at Freiburg. He was not only a profound student of botany but also an excellent artist, his drawings being the admiration and envy of his fellow students. Upon returning to France, he took the doctorate in both medicine and science. He held the positions of assistant professor of botany in the University of Strassburg in 1869, professor of botany at Nancy, 1872, and finally, professor of botany at Bordeaux in 1876, where he remained until his retirement in 1899.

His first work was entirely in pure science but his later years were devoted to economic botany. The introduction of the Phylloxera and the downy mildew fungus, *Plasmopara viticola*, from America, caused Millardet to devote all of his efforts to applied botany. Millardet and his colleague, Planchon, found mildew at about the same time, but in different parts of France in 1878. The introduction, by Millardet, of resistant American vines as stocks for grafting of the European varieties, saved the French vineyards from damage by Phylloxera. His observation of the prophylactic effects against mildew of a copper sulphate-lime mixture used to sprinkle grapevines along the highways to prevent stealing of the grapes, led to the discovery and development of Bordeaux mixture. The discovery of this famous fungicide undoubtedly saved the wine-growing industry of France and is probably Millardet's greatest contribution to science.

F. J. SCHNEIDERHAN



1838-1902

TRANSLATOR'S FOREWORD

The translation of several of Millardet's classic articles about the origin of the copper sulphate and lime mixture, (Bordeaux mixture), as a fungicide, was undertaken in connection with the review of literature for the translator's doctor's dissertation at West Virginia University. The translations were made from photostatic prints of the original articles appearing in the *Journal d' Agriculture Pratique*, found in the library of the United States Department of Agriculture.

It has been the custom, from time immemorial, to sprinkle grape vines along the highways of Médoc, France, with a thick mixture of copper sulphate, lime, and water to prevent thieves from stealing the grapes. Mildew was first observed in France by Millardet in 1878. In October, 1882, he noted that this copper sulphate and lime mixture, used to repel thieves, also controlled mildew. This famous observation is generally considered to have been an accident. May it not have been an incident in the daily work of such an astute observer as Millardet? Be it accident or incident, such was the discovery of Bordeaux mixture.

This discovery is probably as momentous as any event in the whole history of our efforts to control plant pathogens. This fungicide was the first to be used on a large scale the world over. The rapidity of its adoption and general use wherever certain diseases of fruits and vegetables occur, indicates how economically fortunate was Millardet's observation along the highways of Médoc.

F. J. Schneiderhan

TREATMENT OF MILDEW AND ROT

Traitement du Mildiou et du Rot. *Journ. d'Agr. Pratique,* 2: 513-516. 1885.

Since the appearance of mildew in France in 1878, I have not ceased to study *Peronospora* in the hope of discovering in its development some vulnerable point that might permit of its mastery. The results of my observations are set forth in various publications.[1]

I had noticed in the course of my researches that the summer spores or conidia of *Peronospora* easily lose their germinating power. This observation and the failure of all the treatments attempted until then had led me to formulate this conclusion,—*that a practical treatment of mildew ought to have for its objective not the killing of the parasite in the leaves infected by it, which seems impossible without killing the leaves themselves, but of preventing its development by covering, preventively, the surface of the leaves with various substances capable of making the spores lose their vitality or, at least, of impeding their germination.*

Three years ago, therefore, I was in search of a substance that would satisfy my concept, when chance put it into my hands.

Towards the end of October, 1882, I had occasion to traverse the vineyard of Saint-Julien en Médoc. I was not a little surprised to see, all along my way, that the vines still bore their leaves, while everywhere else they had long ago fallen. There had been some mildew that year, and my first reaction was to attribute the persistence of the leaves along the way to some treatment that had preserved them from the malady. Examination, indeed, permitted me to confirm immediately the fact that these leaves were covered in great part on the upper surface by a thin coating of a pulverized bluish white substance.[2]

[1] *Journal d'Agriculture Pratique,* nos. des 10 février 1881, 6 juillet 1882.—*Mémoires de la Société des sciences physiques et naturelles de Bordeaux,* t. V (1884) p. XXIV. —*Zeitschrift für Wein-, Obst-, und Gartenbau für Elsass-Lothringen;* nos. des 1er et 15 mars 1883.

[2] Baron Chatry de la Fosse made the same observation that I did, but two years later, in 1884. It was, in fact, his communication to the Society of Agriculture of la Gironde that, from the first of May, decided me to publish the yet incomplete results of my studies.

After arriving at the Chateau Beaucaillon, I questioned the manager, M. Ernest David, who told me that the custom in Médoc was to cover the leaves with verdegris or with copper sulphate mixed with lime, when the grapes were ripening, in order to keep away thieves who, on seeing these leaves covered with the copperish spots, would not dare to taste the fruit hidden underneath for fear of its having been blemished in the same way.

I called the attention of M. David to the fact of the preservation of the leaves under immediate consideration and shared with him the hope, engendered in my mind, that the salts of copper might form the basis of the treatment of mildew. M. David at first, I must say, made several objections, but finally accepted so completely my ideas and seconded me so efficaciously that it is my duty to ascribe to him the major share in my ultimate success.

The following year (1883) I tested the treatment several times in my garden, either with the material mentioned in the foregoing or with others. M. David repeated the majority of these experiments at Dauzac, in Médoc, on the estate of M. Nathaniel Johnston of which he was manager.

It was the same in 1884 but, by mischance, the mildew was so light in the vineyards where the tests had been conducted that it was impossible to judge accurately of the value of the different treatments that had been applied.

Nevertheless, since there was a certain rumor concerning the treatment by copper sulphate, I decided to share the results obtained with the Society of Agriculture of la Gironde. On the first of May, 1885, I gave the exact composition of the requisite liquid according to M. David's tests and the instructions relative to both the method of application and the most favorable time to apply the treatment.[3]

Following this communication several large landowners of Médoc were not afraid to apply in full the treatment I had recommended.[4] M. N. Johnston, to whom I had confided my ideas in 1882, and who for two years had followed the tests made by M. David, his manager, went into the matter

[3] *Annales de la Société de la Gironde*, 1885, p. 73.

[4] I shall specially cite M. Barton (Chateau Léonville), MM. de Bethmann and Faure (Chat. Gruand-Larose), M. De Ferrand (Chat. Mouton d'Armailhacq), M. Lawton (Chat. de Pez), M. A. Lalande (Chat. Brown-Cantenac), M. Merman (Chat. du Crocq), M. Solberg (Chat. Siran).

in earnest, and he alone had 150,000 vines treated on his two estates at Dauzac and Beaucaillon. The results throughout surpassed my expectations.

Today, the 3rd of October, the treated vines show normal growth. The leaves are healthy and of a beautiful green, the grapes are black and perfectly ripe. The vines that were not treated present, on the contrary, the most wretched appearance, the majority of the leaves have fallen; the few that remain are half dried up; the grapes, still red, will not be fit for anything except sour wine. The contrast is striking. I will add that my colleague, M. Gayon, Professor of Chemistry on the Faculty of Sciences, has been willing to examine the unfermented wines produced by the grapes of the treated and nontreated vines. He found on the same vine (the Malbec):

	Vines treated	*Vines not treated*
Sugar	117 gr. per l.	91 gr. 8 per l.
Acidity produced by sulphuric acid	5 gr. 1 per l.	7 gr. 7 per l.

What enhances still more the value of the experiments of which I am speaking is that they were performed as methodically as possible. In each plat treated there were, as controls, several rows of nontreated vines. I shall point out besides that the treatment was applied preferably to the vines most susceptible to mildew, i.e., the Malbec, the Cabernet franc, and the Petit-Verdot, so that its effects on the less susceptible vines can be only still more satisfactory. Finally, let me add, the disease has this year been exceptionally severe.

All of these considerations, it seems to me, sufficiently warrant my affirming in the most positive manner the efficacy of the treatment, concerning which I speak, against a scourge that, until now, has withstood all efforts in Europe as well as in America; that is to say, mildew, properly speaking, and rot or mildew of grapes. But there is more; the close analogies that exist between the *Peronospora* of the vines and that causing the disease of the potato and tomato cause me to hope that we shall henceforth have at hand a real prophylactic treatment for these latter diseases.

I must now state the nature of the treatment and how and at what time it should be applied.

In 100 litres of water (either well, rain, or river) are dissolved 8 kilos of commercial copper sulphate. Then, from 30 litres of water and 15 kilos of rich rock lime, milk of lime is made and mixed with the solution of copper sulphate. It forms a bluish paste. The workman pours part of the mixture, while stirring it, into a watering pot, which he takes in his left hand, while, with the right, by the aid of a small brush he wets the leaves, taking care constantly not to touch the grapes. One need fear no harm, even to the most tender organs.

At M. Johnston's, 50 litres of the mixture sufficed, on an average, for treatment of 1,000 plants, which, for one *hectare* (10,000 plants), places the total expense (cost of materials and labor) at not more than 50 francs.

The treatment was carried on from the 10th to the 20th of July at several points; the operation was repeated toward the end of August, but without great advantage. It is, therefore, established that a single application is sufficient.

When the mixture dried it adhered well to the leaves. After treatment the vines withstood several storms at the beginning and at the end of August and frequent rains in September. In spite of that, one can still recognize easily today, on more than half of the leaves, the places where they were touched with the mixture. But those that have retained no trace of it are in as good condition as those that are still spotted.

It is not necessary that the leaves be wholly covered by the mixture. I believe it safe to assert that a single spot of it on each leaf is sufficient. This fact it seems to me derives from an examination of the leaves as well as from the comparison of the results obtained from the tests, very carefully executed at M. Solberg's by his manager, M. Feuillerat, with results of treatments performed in an ordinary manner. A mixture of iron sulphate instead of copper sulphate, made by M. Feuillerat, produced good results but was inferior to the copper mixture. Various experiments have proved that copper sulphate alone (at a harmless dose) and lime alone are almost innocuous. The verdigris (500 gr. diluted in 10 litres of water) can, it is true, rival the mixture of copper sulphate and lime but it is much more expensive than the latter.

The experiments of this year show how justified I was in insisting, in my communication of May 1st, to the Society of

Agriculture of la Gironde, upon the necessity of applying the treatment preventively, that is, as soon as the mildew appears in the vineyard. Everybody who has treated vines that were already somewhat seriously affected has realized only the slightest benefit from the operation.

There is a final important item to consider. In spite of all my precautions it happened that a few drops of the mixture fell on the grapes. Will the copper reappear in the wine? And if it be found there, will it be sufficient in quantity to affect the public health?

My colleague, M. Gayon, has been willing to promise me his cooperation to elucidate this question. A preliminary attempt made by him on 800 grams of grapes coming from treated vines has not revealed with absolute certainty any copper. Researches in this direction will continue and I hope in a short time to be in a position to submit the results of them to the wine growers.

MILLARDET
Professor on the Faculty of
Sciences of Bordeaux

TREATMENT OF MILDEW BY THE MIXTURE OF COPPER SULPHATE AND LIME

Traitement du Mildiou par le Mélange de Sulphate de Cuivre et de Chaux. *Jour. d'Agr. Pratique,* **2**: 707-710. 1885.

The salutary effects following the treatment of mildew with the copper sulphate-lime mixture, are accepted today beyond all question. There remains to explain the mode of action of this treatment, why it has been chosen in preference to others, and for what reasons, although probably susceptible to some changes, it appears to me scarcely possible that it will undergo any important modifications.

The observation that led me to conceive the very principle of the treatment dates back several years. I was studying the development of summer spores or conidia of *Peronospora* when I established the fact that the reproductive bodies never developed in water from my well, although when sown in the city water, rain water, or dew and distilled water, they did not delay in completing their evolution by developing zoospores.[1]

The explanation of this strange fact escaped me for some time. It occurred to me only at the very last, as will be seen farther on. As the water from this well is so noticeably impregnated with limestone salts that it cooks vegetables badly, I thought at first that it might have been to this peculiarity that it owed its harmful action on the conidia. But, whatever might have been the cause of this action, I inferred from it that, in any case, *its extremely weak and scarcely discernible effects* were capable of preventing the development of the reproductive bodies of the parasite.

Since, on the other hand, I had taken account of the impossibility of destroying the *Peronospora* without destroying at the same time the leaves stricken by it, for the parasite grows exclusively within these organs until it fructifies, I had arrived at this conclusion, namely, that the treatment for mildew could be only preventive. It should suffice, as I said, to cover preventively the surface of the leaves with divers

[1] This fact appears in the *Annales de la Société d'Agriculture de la Gironde.* 1885, p. 79.

substances capable of causing the summer spores to lose their vitality or, at least, to impede their germination.[2]

I was at that point then, when, in 1882, I witnessed for the first time the favorable action of the mixture of copper sulphate and lime against mildew, a mixture used from time immemorial in Médoc to prevent theft.

It seemed to me that the really active agent in this mixture must have been the copper, in spite of the fact that this metal was in an almost insoluble condition.

So, from the following year, (1883) I devoted myself to uninterrupted research on the efficacy of the different salts of copper (sulphate, carbonate, phosphate, sulphur) and the same salts of iron,[3] as well as on that of the lime in powdered form or mixed in water. These experiments were repeated by M. David of Dauzac at M. Johnston's, who had put his property at my disposal for these experiments, with a generosity for which I can not thank him too much. At the same time, the mixture of copper sulphate was tried in varied doses of the two component materials.[4]

In 1884 the same tests were again performed, but with no definite result, for there was but very little mildew where the tests were made and it was impossible to judge exactly and comparatively the effects resulting from the methods of treatment. However, these two years of research had enabled me, as they had M. David, to recognize the fact that the mixture of copper sulphate and lime was, of all the substances used, the one that had produced the best results. We were induced to give up the iron sulphate and even the copper sulphate treatments, which seem, however, to have given rather good results,[5] because the spraying of these solutions is difficult and they are dangerous to the vine. With a dose of ½ part copper sulphate and 1 part iron sulphate to 100 parts of distilled water, I burned without fail the young shoots and often the leaves wherever the spraying was not very fine and where the liquid collected in drops. Nevertheless, the small quantity of salts deposited on the

[2] *Annales de la Société d' Agriculture de la Gironde, loc. cit.*

[3] I know from my tests that the salts of iron also act favorably against mildew.

[4] All of those tests conducted at Dauzac, with their respective dates, will be found in the diary of the Chateau Dauzac. This important item has been communicated to the commission of the Society of Agriculture of la Gironde for the study of the results of this treatment.

[5] Especially, for MM. Ad. Perrey, P. de Lafitte, Magnien.

leaves by this process appeared to me insignificant in consideration of the end to be attained. Lime alone, applied as a dust, appeared to be almost innocuous. Milk of lime, in a single application, was scarcely more potent.

It is for these reasons that in 1885 we directed all our efforts—M. David and I—in the direction of the copper sulphate and lime mixture, employing it in doses of the two component materials that, according to the tests of the two preceding years, appeared to be the best. It is, indeed, one of the reasons why nowhere else in Médoc the result of the treatment has been so satisfactory as at Dauzac.

In addition to the foregoing, another method gave us results that confirmed those obtained by our direct observation in the vineyard of the effects of the different treatments by the substances mentioned above.

When one places the conidia of *Peronospora* in pure water, at a temperature above 9°C., an hour or an hour and a half thereafter, they discharge zoospores. These move about in the water from 3 to 5 hours, at first rapidly, then stop and put forth germ tubes.[6] These latter pierce the epidermis of the leaf and so penetrate the tissues that, 6 to 8 hours after the beginning of the experiment, the infection of the leaf by the parasite is consummated.

But if one uses dilute solutions of lime, of copper sulphate, or of iron, one will observe that the conidia and the zoospores produced by them are extremely sensitive to these solutions. If the solution is a little too concentrated for the development of the conidia, the latter do not discharge zoospores, but die without undergoing any noticeable change. If the solution is a little less concentrated, some zoospores develop but, in contact with the solution, instead of moving rapidly, they move about slowly and, without germinating, soon come to rest and die. If, following another step, one sows some conidia in a given quantity of distilled water to which one adds, once the zoospores are in motion, increasing amounts of a titrated solution of lime, or sulphate of iron, or copper, there comes a moment when the zoospores stop and are all killed.

The experiment taught me that the limit of concentration of these different solutions, that is the concentration that is

[6] See my memoir *Mildew and Rot*, in *Zeitschrift für Wein-, Obst-, und Gartenbau, für Elsass-Lothringen*, Numbers March 1 and 15, 1883.

incompatible with the complete development of the reproductive germs, is:

For lime, a solution of $\frac{1}{10{,}000}$

For sulphate of iron, $\frac{1}{100{,}000}$ of iron

For copper sulphate, $\frac{2 \text{ to } 3}{10{,}000{,}000}$ of copper

That is to say, the salts of iron, although very active, are nearly 100 times less so than those of copper, and lime is 10 times less active than iron.

It is, therefore, understood that in the experiments of the Bellussi brothers, 5 and 6 successive applications of milk of lime were necessary in order to obtain satisfactory results.

Again, it will be found difficult to secure substitutes for salts of copper because of the prodigious energy of their action upon the reproductive germs of the *Peronospora*.

As for the lime, as will subsequently be seen, its rôle in the mixture appears to be no less important.

It is only after having obtained these results that it has been possible for me, thanks to the cooperation of M. Gayon, to give an account of the fact mentioned above, a consequence that has, in fact, been the point of departure of all my researches: I mean the absence of development of the conidia of the parasite when I sowed them in water from my well.

This well is 11 meters deep. The water is lifted by means of an old copper pump. Analysis has disclosed the fact that it contained 5 milligrams of copper per litre, a quantity more than 10 times that necessary to kill the reproductive germs of the *Peronospora*. I should add that I have lived in the house 6 years, during which time the entire family has drunk of this water without the slightest inconvenience. This fact is interesting because M. Gayon will presently state that, in general, the wines produced from the vineyards that have been given the treatment under consideration contain hardly a 16th part of the copper found in the water of which I have just spoken.

Another obscure but very interesting fact, about which I must speak, could be elucidated only by a chemist. It is again to the cooperation of my learned colleague that I owe its explanation.

Copper in the mixture and on the leaves is found as an hydroxide, which is generally regarded as insoluble. Under the microscope it is observed in the form of amorphous granules at first united by the lime and the sulphate of lime, and later protected by a solid and slightly soluble crust of carbonate of lime.

Now, it happens, according to studies conducted by M. Gayon, that this oxide is dissolved slowly but integrally at 15° C. by water containing in solution some carbonate of ammonia; that water containing carbonic acid can dissolve 40 milligrams of the oxide per litre at the same temperature and atmospheric pressure; and, finally, that pure water itself dissolved traces of this same oxide at 15°C.

The little drops of the mixture disseminated over the leaves, therefore, function like true reservoirs of copper oxide, which, for weeks and months, retain the oxide under the protection of their limestone coating and furnish to the water of dew or rain, more or less charged with carbonate of ammonia and carbonic acid, the minimum quantity of the copper necessary to check the development of the conidia that the wind deposits on the surface of the leaves. The lime seems to me, then, to play a triple rôle in the mixture. At the moment of spraying it acts like an energetic mordant which fixes the disinfecting drop on the leaf and establishes its close adherence. For several days, it is capable of killing the conidia and zoospores by its causticity. Finally, when it has been transformed into carbonate, it serves for the preservation of the store of copper oxide.

If the theory I have just presented were in need of proof, one would find it in the following experimental fact, that several persons have this year found out, in Médoc, that the treatment produced its maximum effect there only when it was applied in a preventive manner. As early as the first of last April, I had insisted forcibly upon this important point.[7]

In the issue of last October 8 of this journal, as well as in my communication of the 5th of the same month to the Academy of Sciences, I presented the copper sulphate and lime treatment as a remedy both for mildew and rot. Permit me to present a brief elucidation of this subject.

It was in 1883, in Europe as I have already mentioned, that I first described and illustrated rot in the Alsacian

[7] In the *Annales de la Société d' Agriculture de la Gironde, loc. cit.*

journal cited above. Rot is produced, as I have clearly established, by the development of mildew on the clusters of the bunch and within the grapes. That is, I believe, the most common variety of rot in America and probably the most important for us. Since completing the work of which I have just spoken, I have learned to recognize another kind of rot, which develops subsequent to the anthracnose on the grape clusters of the bunch. Finally, following some recent disclosures, which require confirmation, there seems still to exist a third kind of rot caused by a fungus of the genus *Phoma*.

When I stated in one of my preceding articles that the treatment of mildew likewise prevents the rot, I had in mind only the first kind of rot mentioned above, i.e. that associated with the mildew. It is, in fact, true that, while preventing the development of mildew on the leaves, one at the same time prevents the invasion of the bunch of grapes by the same parasite.

MILLARDET
In collaboration with M. Gayon.

CONCERNING THE HISTORY OF THE TREATMENT OF MILDEW WITH COPPER SULPHATE

Sur l'Histoire du Traitement du Mildiou par le Sulfate de Cuivre. *Journ. d'Agr. Pratique,* **2**: 801-805. 1885.

Thanks to the efforts of a large number of observers and experimenters we now know of an agent capable of preventing the disastrous effects of mildew. It is not only established that the salts of copper, especially the sulphate, constitute a certain preventive treatment of the plague, but we have at hand certain practical methods of administering the treatment. It has interested me to investigate by what steps this discovery occurred and to place the results of the research before the public.

The first mention with which I am acquainted relative to the use of copper sulphate against mildew is found in a work on the development and treatment of mildew and rot published by me on the 15th of March 1883.[1]. In fact, one finds there the following, near the close of the article: "Some recent observations lead me to hope that we may perhaps obtain more satisfactory results through the spraying of certain mineral solutions, sulphate of iron or copper, for instance."

The recent observations to which I refer are those that I made, as I said before, at the end of October 1882, relative to the beneficial effects from spraying with the Médoc mixture.

In the recent work of M. P. Lafitte[2] it is noted that on the 20th of September, 1884, M. Ricaud and M. Paulin published in the *Journal de Beaune* a note on the verification of the good effect of a concentrated solution of copper sulphate on the white wooden props treated the year before in Bourgoyne. M. Ricaud cites the fact, as noticed recently. On the 23rd of the same month and in the same journal, again quoting M. Lafitte, is a note by M. Montoy on the same subject.

Finally, according to the same author, M. Bidaud would have written on the same subject and in the same journal,

[1] *Zeitschrift für Wein-, Obst-, und Gartenbau für Elsass-Lothringer,* numbers for March 1 and 15, 1883.

[2] *Journal d'Agriculture practique,* number for October 1, 1885, p. 479.

current for the month of September but on a date not stated by M. Lafitte.

The original publications in question are unknown to me. But it seems certain to me while writing what we have just read (I have done nothing but copy M. Lafitte word for word) that the author of whom I speak was well informed.

I read, in effect, on page 5 in the notes of the Bulletin of the Committee on Agriculture of the Beaune district, October, 1885, that "The newspapers of Beaune published in support of the efficiency of sulphated props, some articles by MM. Ricaud Paulin, and Montoy in Nos. 20 to 23, September 1884.

These communications were soon followed by one from M. Ad. Perrey to the Academy of Sciences. Beginning with the 29th of the same month, M. Perrey communicated to the Academy the same observations and so discussed them as to place the action of copper sulphate beyond all doubt. His note terminated with the following words "Without wishing to exaggerate the results of an observation that numerous testimonials will without doubt soon confirm, we limit ourselves to introducing the prophylactic agent, counting on the common effort of those interested to hasten the moment when the application will be made general through economic procedure."

With these last words M. Perrey seemed to promise to study, by himself, the action of copper sulphate on mildew. He kept his word, as we shall subsequently see.

Such, to my knowledge, are the first published documents concerning the action exercised by copper sulphate on the deadly parasite. It is fitting and right to accord the honor of it to the Burgundians, in general, and the Committee of Beaune, in particular.[3]

On the third of December, the same year, a large property owner of Médoc, M. le baron Chatry de la Fosse, called to the attention of the Society of Agriculture of la Gironde the salutary effects of a mixture of lime and copper sulphate on mildew. They have the custom in Médoc of

[3] It is, no doubt, worth mentioning here a communication made to *Progrès agricole* of November 4, 1884, by M. P. Estéve, of Montpellier, on a powder devised by him called *Sulfatine*. This powder consists of sulphur, copper sulphate, iron sulphate, and calcium sulphate. According to its inventor, it has for two years been effective against mildew. The exact amounts of the various ingredients that make up *Sulfatine* have not been given out by M. Estéve, who is advertising his discovery.

spraying the vines along the roads with this mixture to keep away thieves. A few weeks later M. de la Fosse imparted his knowledge to his colleagues of the French Society of Agriculture.

The first published communication of any moment that I contributed personally concerning the use of copper sulphate is contained in the Annals of the Society of Agriculture of la Gironde under date of April 1, 1885. This communication was published on the 1st of May in the Journal of Agriculture and Horticulture of la Gironde. Will you permit me to review it hastily in order to show that it represents a notable advance over its predecessors?

In it I stated, in effect, how I had been impressed in October, 1882, that is, two years before M. de la Fosse, by the salutary effects on mildew common in Médoc resulting from the application of copper sulphate sprays to vines and grapes along the highways in order to prevent pilfering. I told of the tests that I, alone, had made in my own garden, or with the help of M. David, manager of the Duchy of Dauzac (Médoc), performed on a large scale relative to the efficacy of different salts of iron and of copper, in 1883 and 1884. Finally, I announced the formula of the mixture, which, after two years of research, seemed to give the best results, and the exact directions as to the time when the treatment should be applied. I shall add that the same explanation of the action of the treatment is, in brief, to be found in this document.[4]

[4] I shall quote some passages: "Here is how one may prepare the preservative mixture:—In 100 litres of water (well, rain, or river) dissolve 8 kilos of commercial copper sulphate. Then mix with the copper sulphate solution a solution consisting of 30 litres of water and 15 kilos of rich rock lime. It will form a bluish deposit. The workman pours, while stirring, part of the mixture into a bucket or into a sprinkling can, which he takes in his left hand; while, with the right, with the aid of a little brush broom, he sprinkles the leaves with the preservative solution, being careful to prevent its reaching the grapes." I shall note the fact that the treatment ought to be preventive; that it in no way reacts so as to destroy the *Peronospora*, but simply prevents its germ tubes from penetrating the interior of the leaf. Now, the mildew occurs in the vineyards scarcely ever before mid-June. Prior to that time the owners can devote their leisure to the treatment of other pests of the vine. But from that time forward, through the months of July and August, especially, they must be constantly on the watch in order that immediately, from the first evidence of the parasite, the fungicide may be applied within 24 hours, *at least as a preliminary test.* No injury must be permitted to happen, especially to the shoots and the tenderest buds. Such can obtain only if all the copper sulphate is broken down by the milk of lime and enters into a condition of a hydrate of copper oxide, which apparently dissolves only very slowly and in infinitesimal quantities in water spread on the surface of leaves by rains, mist, or dew."

It is generally known what has happened since. Following the communication, several large proprietors of Médoc did not hesitate to treat large areas of vineyards in accordance with the procedure I had worked out and recommended. The results were the most remarkable in the degree that my recommendations were faithfully followed in these treatments, and nowhere were they so complete as on the estate of M. Johnston of Dauzac and Beaucaillon, where the treatment had been directed by M. David who, for two years, had been experimenting on a small scale. The area treated by M. Johnston alone was about 25 hectares.

I should add another fact, still unpublished, in order that my statement may be complete. Having been consulted in the early part of August by one of my Italian correspondents M. Giuseppi Rebora, of Novi (Liguria), I described to him the treatment in question. As early as mid-August he applied it to 10 hectares of vines. Some neighbors followed his example. Among the persons to whom he described this method of treatment was M. le marquis G. Pinelli Gentile, of the Chateau Tagliolo, who treated 80 hectares of vines. Everywhere, the result was completely satisfactory.

I have given an account of these facts, save the last one, in my communication of October 5 before the Institute, which was published in the issue of October 8 of this journal. In two more recent notes, in collaboration with M. Gayon,[5] I pointed out the harmlessness to the wine from the treated vines and I fully explained the action of the treatment.

In the meantime, M. Perrey, who, on the 29th of September, evidenced the beneficial effects of sulphated props on mildew, tried a copper sulphate solution in Bourgoyne. He communicated to the Academy, for its October 5 meeting, detailed instructions concerning the technical part of the treatment, the same day on which I published the results of the treatments made at my suggestion at Dauzac. A solution of 5 per cent was applied by means of a hand sprayer. The total area of the 4 sections treated, although a little less than 1½ hectares, is entirely sufficient to judge the true worth of the procedure. It undoubtedly will be necessary to compare carefully from all points of view the one that I have proposed in order to determine the relative values of the one and the other.

[5] See numbers for 12th and 19th of November.

Finally, on the second of November, M. Muntz, professor at the Institute of Agronomy, wrote to the Academy concerning the results of experiments conducted by the same method in the Southeast, that is, by spraying a 10 per cent solution of copper sulphate. In that case, also, the treatment was followed by good results.

However, some other facts prior to those of which I have just spoken and of a different nature need to be added in order to corroborate or, rather, complete them.

In the past year, 1885, M. Lafitte, to whom the observations made in Bourgoyne the preceding year concerning the efficacy of sulphated props were known, began at Agen some careful experiments to clear up this fact, still contested by many persons in the Southwest. On the 22 of September he wrote to the Minister of Agriculture in order to lay before him certain remarkable results that had been obtained from these experiments.[6] They show, in fact, as clearly as can be desired, the salutary effect of the sulphated props and ties on mildew.

Others in Burgundy made some observations and experiments in 1885 that confirmed all of these facts. For example, MM. Magien,[7] Professor of Agriculture of Côte d'Or, Montoy, Vice President of the Committee of Agriculture of Beaune, and several others, the names of whom one may read in the report of M. Montoy.[8] One of the most interesting facts proved by the Burgundians is the efficacy of the sulphating of straw ties, of which they make use in this country to fasten the vine to the prop, or a small handful of sulphated straw, attached with the branches to the upper part of the props.[9]

One finds in the bulletin of which I am speaking an account of an experiment made by M. Bouchard, President of the Chamber of Commerce, which confirms and extends the conclusions of MM. Perrey and Muntz concerning the action of copper sulphate dissolved in water. A 3 per cent solution applied by means of the Riley sprayer was followed by very good results.

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[6] This relationship is reported in the October 1 number of this journal.

[7] See *Journal d' Agriculture*, No. for October 31, p. 712.

[8] *Bulletin du Comité d' Agriculture de l'arrondissement de Beaune*, October, 1885, p. 4 to 10.

[9] Ibid.

But the most important fact contained in the publication of which I speak is the corroboration of the efficacy of a dust with a base of copper sulphate and lime made by Louis Podechard, a winegrower of the hamlet of Gigny.

This dust is made essentially like the mixture I suggested. It is possible that it may prove to be a valuable addition or even a perfection of the latter. It certainly will be worth while to compare it carefully either with this or with the spray treatment proposed by M. Perrey, for nothing is proved by saying that a treatment that gives good results in Burgundy will suffice for the Southwest, and *vice versa*.

It remains for me to point out a recent contribution by M. B. Chauzit, Professor of Agriculture at Gard, who, by various kinds of experiments with copper sulphate, said he obtained only unsatisfactory results.

This hasty review would, I believe, suffice to make appreciable the part played by each in the great victory just obtained against mildew, if I had not purposely passed sketchily over the important facts in order not to prolong my account. I shall revert to them in closing.

On the first of last October, in inviting the public to assure itself of the beneficial results of the treatment at Dauzac I stated in the Journal of Agriculture and Horticulture of la Gironde, that I had first conceived, experimented with and recommended the practice of this treatment. When I say this *treatment*, I mean a treatment by copper. I would like to prove before putting my pen aside that this proposition is in no wise exaggerated and is, even today, a statement of fact.

It will be found that I first conceived the idea of a treatment by copper in a letter that M. David wrote me in December, 1884, in which he recalled the observation I had made in October, 1882, concerning the beneficial effects of the Médoc mixture of copper sulphate.

"You were right in attributing 2 years ago," he said to me, "to the spraying of leaves practiced along the highways to prevent pilfering, their good state of preservation and resistance to mildew." I hold the original of this letter at the disposal of any who may desire to be convinced of the truth of my assertion. It has been transmitted to the Society of Agriculture of la Gironde and is now in the hands of the National Society of Agriculture.

But another proof, still more decisive than the one of which I have just spoken, since it rests upon a well-known fact, is stated in a simple sentence that I cited at the beginning of this article and published, as has been seen, since the 15th of March 1883. I presented in it the opinion founded on recent observations that the sulphate of copper acted more effectively against mildew than all the others employed up to that time. Now, it seems to me, and I do not believe I am mistaken in this, that this simple observation possesses all the merit desirable in such a matter when it is shown that such observation was followed by several careful experiments, which would have been decisive in 1883 or 1884 had not chance prevented the results from being fully appreciated.

The proof that these experiments had been performed this same year, 1883, is found in another publication, which, like the preceding one, was presented before the commission named by the Society of Agriculture of la Gironde and has since been placed at the disposal of the National Society of Agriculture. There is an authentic copy of the passages in the original, with various notes, in the record of the work at the Chateau Dauzac during the occupancy of M. E. David, manager for M. Johnston, who reported on the experiments made at Dauzac, at my suggestion or inspiration, during the three preceding years. The document, which has not less than seven large pages, contains, with their respective dates, the account of the most important tests concerning the action of copper sulphate and sulphate of iron, whether as a dust or as a mixture with lime, on the dosage of the different elements in the mixture, on the other methods of treatment, etc. The first of these experiments dates from the middle of August, (the 18th, as near as I can recall, for I cite from memory) 1883. In 1884 these were conducted in the same manner. But it so happened that, in 1883 as in 1884, Dauzac was nearly free from mildew, a fact that prevented M. David and me from obtaining from these tests all the information we had a right to expect. Therefore, it was not until 1885, that is, three years from the inception of the research, that success crowned our efforts. There is no doubt that had mildew raged in Dauzac in 1883 our tests would have been sufficiently numerous and methodical to serve as a basis for entirely effective treatment. The incalculable

losses caused by the epidemic in these last two years would thus have been spared the wine growers.

I shall without doubt be granted the right to state that I first conceived and experimented with the copper sulphate treatment. It seems to me impossible that anyone would object to my adding the fact that I first recommended the use of the treatment. For this, as we have seen, is the treatment that has given remarkable results at Dauzac as recorded by Prillieux in his excellent report.[10] This treatment, I state, is found described down to the smallest detail in my communication to the Society of Agriculture of la Gironde on the 1st of April 1885. At this time, that is to say, at the moment when I was formulating the prescriptions for it, prescriptions that have received the sanction of the most striking success in France as well as in Italy, no one had anything other than more or less vague and incomplete data on the method of applying copper sulphate as a treatment for the epidemic. I claim the honor of having conceived the treatment with copper, that of having first experimented and, likewise, of having first proposed the practice. May I be permitted to add—for these are for us learned men our titles and our dearest souvenirs—that first, in 1878, simultaneously with M. Planchon, I observed the presence of mildew in France. Since then I have constantly been on guard. My work gives evidence of it.[11]

MILLARDET

November 21.

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[10] I would have made many reservations as to the manner of presenting the facts in this report had not M. Prillieux, himself, declared that he alone intended to state the facts.

[11] I seize this occasion to reply to the objection made by M. Prillieux in the number of the journal preceding the last one (p. 723). It is true that the works cited by M. Prillieux preceded my memoir published in the *Zeitschrift*, etc. But, in my article: *Mildew in the Southwest in 1882*, printed in the August 21st 1882 number of the *Journal d'Agriculture pratique*, I gave the most circumstantial description of the *Rot of Jacques*, and, curiously enough, some of the same Jacques plants that served M. Prillieux for his notes of September 18 and October 2 of the same year. I therefore, reserve priority as I have stated.—M. Prillieux would not have raised this objection had my citation been more complete and precise. Of two notes that I was able to cite, I chose the most complete, the one that presents some figures but postdates the other by six months. I express my consequent regrets to my learned colleague of the Agronomic Institute. A.M.